# The Relativistic Heavy Ion Collider

# BNL/PHENIX Group

**David Morrison** 

DOE NP RHIC Science & Technology Review 23 – 25 August 2016



a passion for discovery



# Group composition and responsibilities

- Primary responsibility is operation of PHENIX experiment, hosting of activities –
  e.g, visitor support, computing, meetings, publication support and research
  activity to optimize scientific output of the collaboration.
- Model of strong research involvement with PHENIX has been very successful areas of particular expertise (e.g., neutral pions, photons, global observables, fluctuations), and ability to attract capable scientists
- Group leader (Morrison), two deputies (Steinberg, Woody) work in conjunction with leaders of specific activities to coordinate and direct effort of group
- Current PHENIX activities include technical crew working on PHENIX R&R
- Activities directed toward anticipated sPHENIX project
  - detector prototypes and test beam activities
  - sPHENIX project management
- ATLAS HI physics analysis & ZDC project lead
- · R&D (LDRD, PD, PECASE, TSAs (tech. service agreements), EIC R&D)

#### **PHENIX**

- D. Morrison, GL
- P. Steinberg, DL
- C. Woody, DL
- M. Faulkner, GA
- B. Azmoun
- J. Biggs
- S. Boose
- M. Chiu
- G. David
- E. Desmond
- A. Franz
- P. Giannotti
- J. Haggerty
- J. Huang
- E. Kistenev
- J. La Bounty
- W. Lenz
- M. Lenz
- D. Lynch
- E. Mannel
- J. Mills
- R. Nouicer
- E. O'Brien
- C. Pinkenburg
- R. Pisani
- S. Polizzo
- C. Pontieri
- M. Purschke
- T. Sakaguchi
- I. Sourikova
- S. Stoll
- Y. Suenaga
- A. Sukhanov
- M. Tannenbaum
- F. Toldo
- J. Tradeski

#### PHENIX

PHENIX Scientific Collaboration Yasuyuki Akiba — Spokesperson
Julia Velkovska — Deputy Spokesperson
Stephan Bathe — Deputy Spokesperson
Sasha Bazilevsky — Deputy Spokesperson

Jamie Nagle, Dave Morrison co-spokespersons through 2015

Publication support: Brant Johnson (RIF July 2016; contract for 20% FTE)
Web support: Hyon-Joo Kehavias (voluntary RIF December 2015)

#### **Executive Council**Christine Aidala

Tom Hemmick

Itaru Nakagawa
Megan Connors
Marzia Rosati
Ralf Seidl
Jin Huang (appointed)
Joel Osborn (appointed)
Jamie Nagle (appointed)
Bill Zajc (appointed)
Yasuyuki Akiba (ex officio)
Julia Velkovska (ex officio)
Stephan Bathe (ex officio)
Sasha Bazilevsky (ex officio)
Mickey Chiu (ex officio)

#### Analysis Coordinator Stephan Bathe

Computing Coordinator
Chris Pinkenburg
G4 Simulation Coordinator

Chris Pinkenburg
G3 Simulation Coordinator
Hubert van Hecke

VTX Software Coordinator Takashi Hachiya

HHJ Nathan Grau Marzia Rosati Hubert van Hecke

#### PLHF

Takao Sakaguchi Axel Drees Maya Shimomura

#### Spin

**Physics Working Groups** 

Sanghwa Park Ralf Seidl

#### **PHENIX Operations**

Mickey Chiu — Director

John Haggerty — Deputy Director

Don Lynch — Chief Engineer

#### **Topical Groups**

Gabor David (RIF July 2016) —  $\gamma$  and neutrals Craig Ogilvie — jets Cesar da Silva — quarkonia Matt Durham — HF electrons Sasha Lebedev — VTX Mickey Chiu — MPC Ermias Atomssa — HBD Shengli Huang/Aneta Iordanova — Cu+Au  $W \leftarrow e$  working group  $W \leftarrow \mu$  working group

#### **Detector Council**

Toru Sugitate — BBC Cheng-Yi Chi — DAQ

Achim Franz (moved to Dept. ESSH) — Data Production

Victor Riabov — DC

Justin Frantz — EMCal PbGl

Edouard Kistenev — EMCal PbSc

Melynda Brooks — FVTX

Itzhak Tserruya — HBD

John Lajoie — LVL1

Achim Franz (moved to Dept. ESSH) — Magnets

Ken Read — MuID

Mike Leitch — MuTr

 ${\sf Matthias\ Grosse-Perdekamp-MuTrigger}$ 

Vicki Greene — PC

Hideki Hamagaki — RICH

Chris Pinkenburg — Simulations

Yasuo Miake — TOFE/Aerogel

Julia Velkovska — TOFW

Yasuyuki Akiba — VTX

John Haggerty — ZDC

#### Run Coordinator

Denis Jouan

Trigger Coordinator

Sasha Bazilevsky

Spin Coordinator Ralf Seidl

**DAQ Coordinator** 

Martin Purschke

#### Office of Nuclear Physics sPHENIX J. Gillo Director of Facilities & Project Management Div E. Bartosz Program Manager BHSO F. Crescenzo Site Manager L. Nelson Federal program Director BNL Nuclear and Particle Physics Directorate B. Mueller Associate Lab Director Project Management Group D. Lissauer T. Roser Deputy Associate Lab Directors BNL Physics Dept **Project Office** L. Littenberg E. O'Brien Project Director J. Dunlop J. Haggerty Project Manager - Science sPHENIX Scientific Collaboration J. Mills Project Manager - Engineering Gunther Roland & Dave Morrison — Co-spokepersons D. Lynch Chief Engineer I. Sourikova Project Controls **Project Management Office** Support Office R. Ernst Resource Coordinator **WBS 1.1** P. Giannotti ES&H I. Sourikova **Executive Council** sPHENIX Topical Groups J. Eng QA R. Ernst Megan Connors (junior) Sarah Campbell (junior) Tom Hemmick **Engineering and Facilities** Science **Upsilon Spectroscopy** cold QCD **Jet Structure** Heavy Flavor Jets John Lajoie J. Mills J. Haggerty Anne Sickles Tony Frawley Rosi Reed Jin Huang Christine Aidala Bill Zajc Marzia Rosati Dennis Perepelitsa Mike McCumber Nils Feege WBS 1.2 Magnet WBS 1.3 Tracker Joern Putschke K. Yip I Nakagawa Silicon Jamie Nagle T. Hemmick TPC Huan Huang WBS 1.8 Infrastructure Itaru Nakagawa P. Giannotti WBS 1.4 EMCal Christine Aidala C. Woody Ed OBrien (ex officio) Gunther Roland (ex officio) WBS 1.9 Install & Integration WBS 1.5 HCal Dave Morrison (ex officio) D. Lynch J. Lajoie **WBS 1.6 CalElectronics** E. Mannel

WBS 1.7 DAQ/Trigger CY Chi

### PHENIX Operations

BNL/PHENIX group has provided key support to maintain and operate detector, and to build and improve equipment

red = DC Member/Subsystem Leader

DAQ - Martin Purschke, Ed Desmond, John Haggerty, Mickey Chiu

ONLCAL/ONLMON/RCF Liaison - Chris Pinkenburg

**ZDC – John Haggerty** 

MPC - Mickey Chiu

MPC-EX - Edward Kistenev, Andrey Sukhanov, Steve Boose

EMC - Edouard Kistenev, Sean Stoll, Jeff Mitchell

RICH - Takao Sakaguchi

VTXS/VTXP - Rachid Nouicer, Eric Mannel, Mike Lenz, Rob Pisani

**FVTX** – Jin Huang

HV - Martin Purschke, Sal Polizzo

LV - Steve Boose, Sal Polizzo, John Haggerty

Safety Systems - Paul Giannoti, Frank Toldo

Gas Systems - Carter Biggs, Rob Pisani, John Tradeski

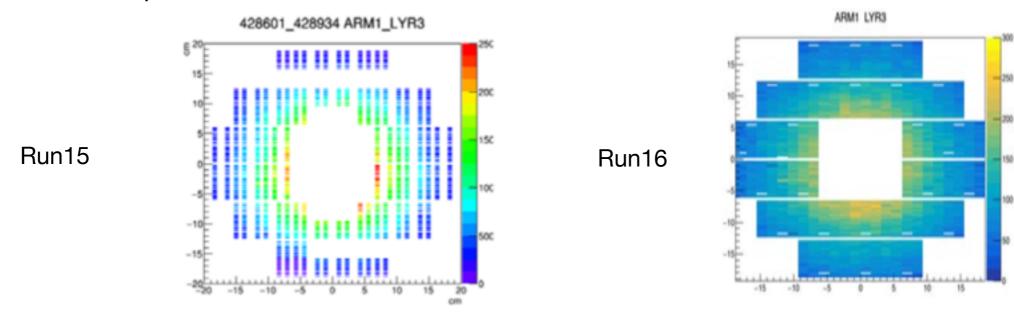
Slow Controls - Steve Boose, John Haggerty, Frank Toldo

Magnets – Achim Franz

Infrastructure Support - Carter Biggs, Don Lynch, Jimmy Labounty, John Tradeski

### PHENIX Operations - maintain/improve detectors

- 1. MPC-EX W-Si preshower for forward direct γ
  - FEM+Carrier Boards: A. Sukhanov (moved to C-AD)
  - HV/LV Distribution Boards: S. Boose
  - DAQ Integration: E. Desmond, M. Purschke
  - Mechanical Design: D. Lynch, R. Ruggiero
  - Installation: J. Labounty, C. Biggs, F. Toldo
  - Firmware improvements Run15 to Run16 ⇒ 95% live



- 2. VTX/FVTX cooling system improvements for Run15
  - Run14 static discharge and condensation issues
  - No issues in cooling system for Run15/16
- 3. Repair of MPC and VTX damaged by beam dumps in Run15 p+Au
  - Protection diodes added to MPC
  - VTX-S ladders reconfigured to maximize live area

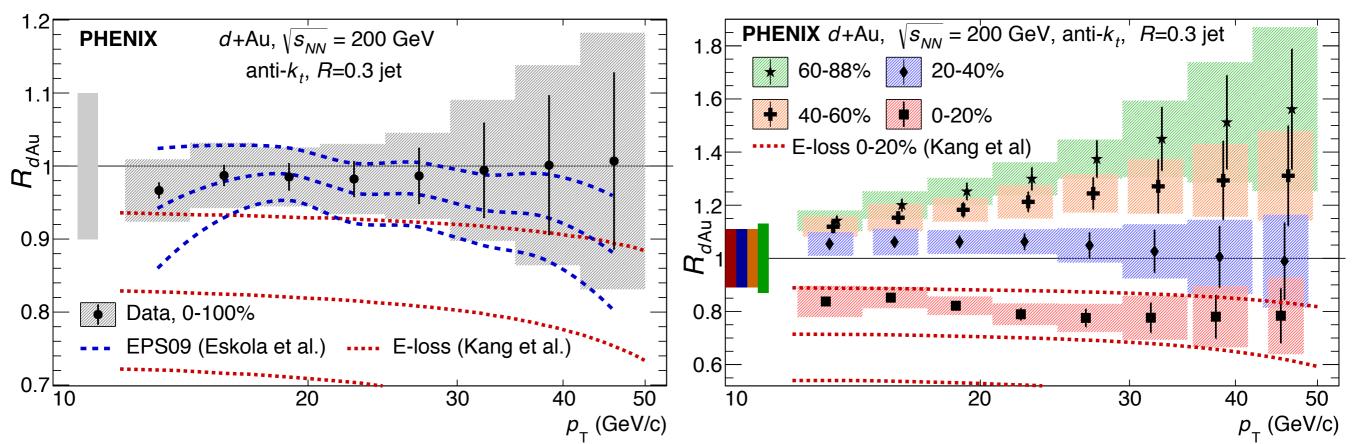
### Scientific productivity since 2014 S&T review

- 5 IAC spots
- 8 LOC spots (including conveners at conferences)
- 45 invited seminars and talks
- Primary authors or on internal review committees or editors on 59 refereed papers (PHENIX, ATLAS, sPHENIX, few author, review and white papers)

# Jet production in d+Au

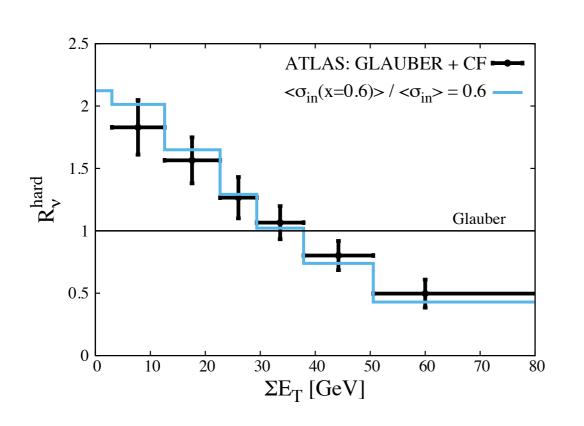
Dennis Perepelitsa a primary author Goldhaber Fellow BNL → Colorado

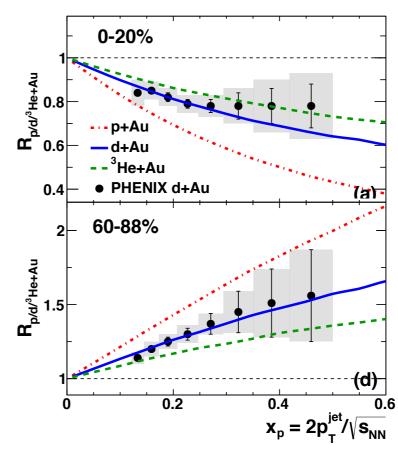




- PHENIX Collaboration, Centrality-dependent modification of jet-production rates in deuteron-gold collisions at  $\sqrt{s_{NN}}$  = 200 GeV, Phys. Rev. Lett. 116 (2016)122301
- Measurement of nPDF / cold-nuclear matter effects over large kinematic range at RHIC
- First measured jet spectrum in non-p+p collision system at RHIC finalizes QM'12 result; observation of qualitatively similar effects to p+Pb data at LHC

### Possible x-dependent proton size fluctuations

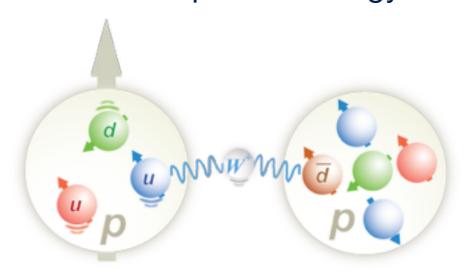




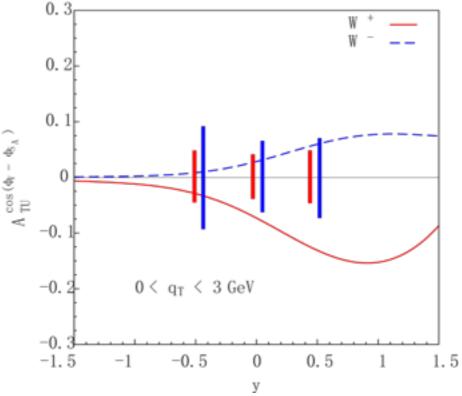
- Alvioli, Cole, Frankfurt, <u>Perepelitsa</u>, Strikman, Evidence for x-dependent proton color fluctuations in pA collisions at the CERN Large Hadron Collider, Phys. Rev. C93 (2016) 011902
  - explanation of p+Pb effects at the LHC as arising from "shrinking" or "weakly interacting" proton, with quantitative comparison of model to data
- McGlinchey, Nagle, <u>Perepelitsa</u>, Consequences of high-x proton size fluctuations in small collision systems at RHIC, nucl-th/1603.06607, Accepted by Phys. Rev. C
  - → proposal to test shrinking proton picture with p/d/³He+Au data at RHIC

# Huang, Kang, Vitev, Xing, PRD 93 (2016)

Within TMD factorization formalism, presents the cross sections for weak boson production in polarized pp collisions. And estimated the spin asymmetries at the top RHIC energy.

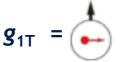


- Curve: Huang, Kang, Vitev, Xing, PRD 93 (2016)
- Points: Jin's naïve expectation of STAR Run17 projection based on Sivers A<sub>N</sub> projection in RHIC Cold QCD plan



 $p^{\uparrow}p \rightarrow W + X \rightarrow (e+v)+X$ , transversely polarized p+p collision @  $\sqrt{s} = 510$  GeV

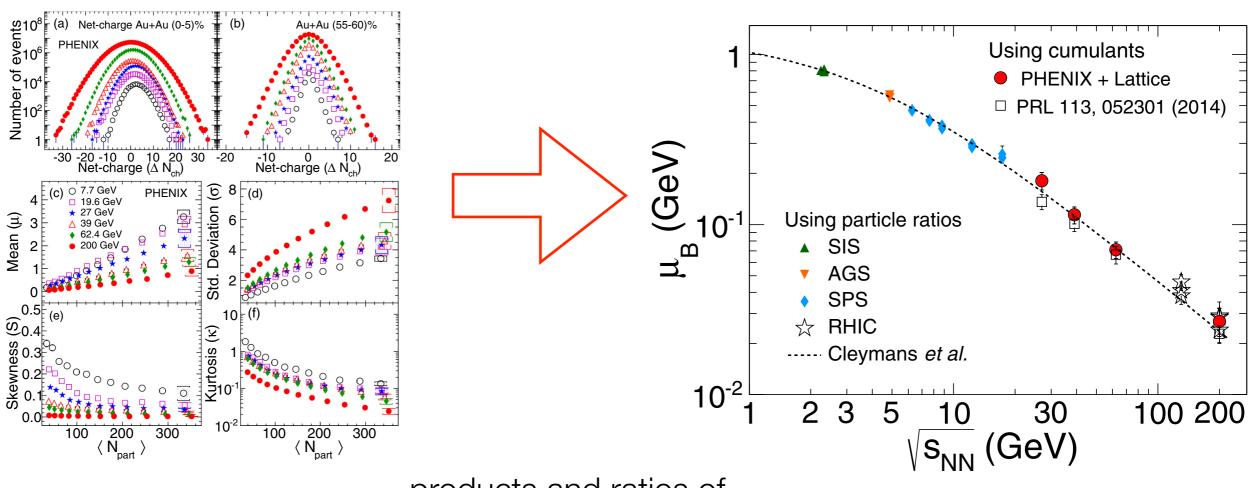
Unique opportunity of probe transversal helicity  $g_{1T}$  via parity violating single transverse spin asymmetry. With Sivers measurements, comprehensively tests universality properties of TMDs, constrains the TMD evolution effects





# Net charge fluctuations

"Measurement of higher cumulants of net-charge multiplicity distributions in Au+Au collisions at  $\sqrt{s_{NN}} = 7.7-200$  GeV", Phys. Rev. C 93, 011901(R) 2016 (primary authors include Jeff Mitchell (moved to EBNN), Mike Tannenbaum)



uncorrected net charge distributions

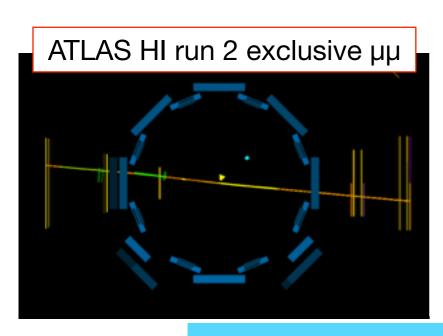
products and ratios of cumulants of fully corrected distributions – dependence on volume drops out

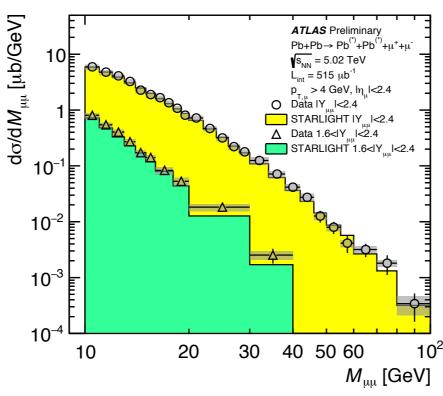
with input from LQCD, determine  $\mu_B$  and  $T_f$  vs  $\sqrt{s_{NN}}$  with small uncertainties

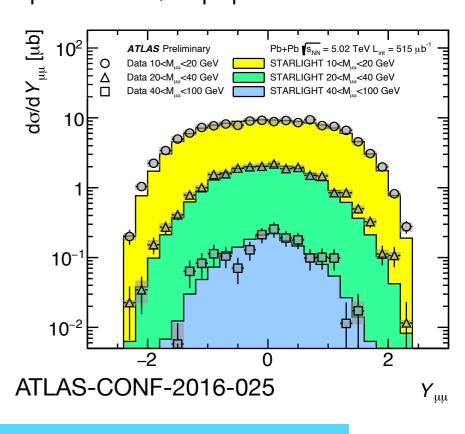
# Ultra-peripheral physics in Pb+Pb with ATLAS

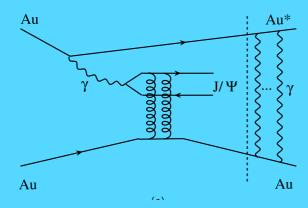
STARLIGHT MC implements collisions of Weisacker-Williams quasi-real photons + QED  $\mu^{\pm}$  production

Strong EM fields, highly contracted: source quasi-real photons to probe nucleus (& nucleon in *p*+Pb).









Photon-pomeron:
production of vector mesons
(sensitivity to nPDF)

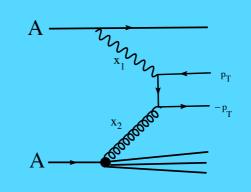
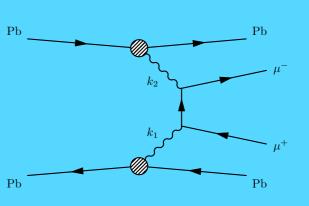


Photo-nuclear:
jet photoproduction
(probe nPDF directly)



Photon-photon: dilepton production (& other exclusive states)

# sPHENIX physics

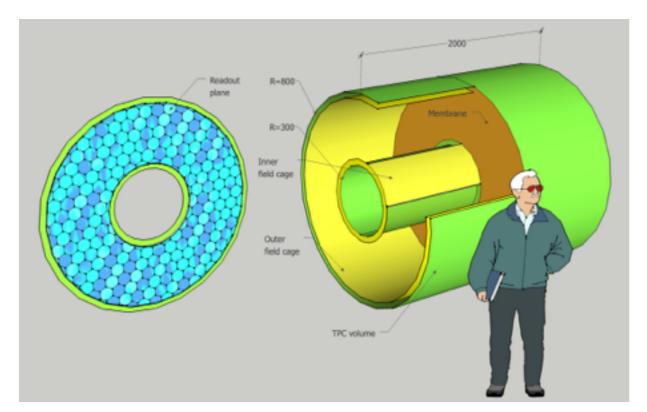
- sPHENIX science case (Morrison, Huang, Perepelitsa)
  - Jet b-tagging studies, now with full GEANT4 detector simulations (Perepelitsa)
  - EMCal simulations studies of 1D vs 2D projectivity and relevance to Upsilons (Huang)
- Co-conveners of sPHENIX topical groups (Huang, Perepelitsa)
- Computational framework, code development, simulations (Pinkenburg, Purschke, Huang)

# Tracking R&D

# sPHENIX requirements Upsilons with Δm/m ~ 100 MeV/c; DCA < 100 μm; pattern recognition in central HI (and in jet cores)

Time projection chamber for sPHENIX tracking

- Fast, compact TPC with GEM readout
- Potentially reusable for eRHIC detector



SBU+Woody, Azmoun, Sakaguchi

Investigation of possible intermediate silicon strip tracker: Hamamatsu sensors being tested



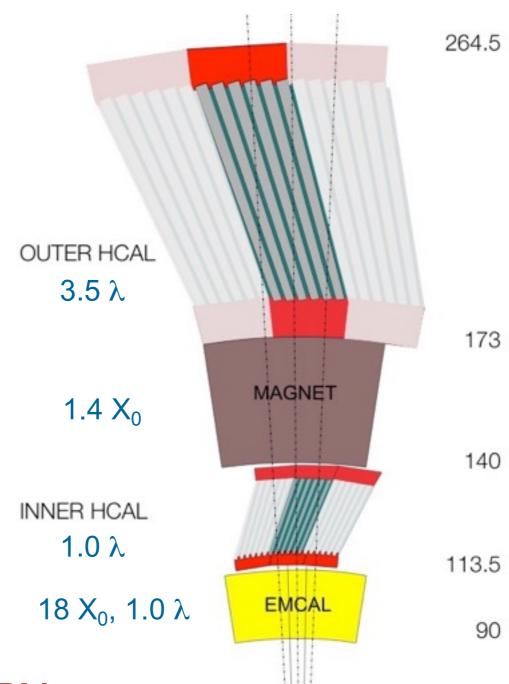
RIKEN+Nouicer

### sPHENIX Calorimeters

#### azimuthal slice of sPHENIX

HCAL – Steel plates + scintillating tiles with WLS fiber readout

EMCAL – Tungsten SciFi SPACAL
– based on UCLA design, with
extensions to 2D projectivity and with
large scale production innovations



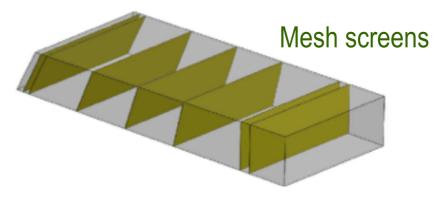
Both EMCAL and HCAL read out with SiPMs

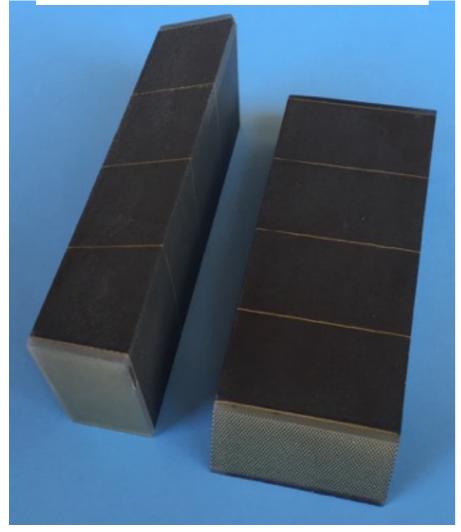
EMCAL + HCAL  $\sim 5.5 \lambda$ 

### W/SciFi Modules

#### UIUC+Woody, Stoll

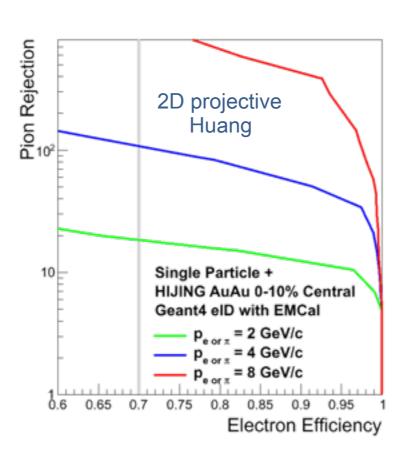
#### 1D Projective



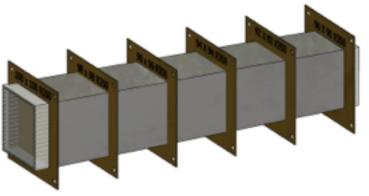


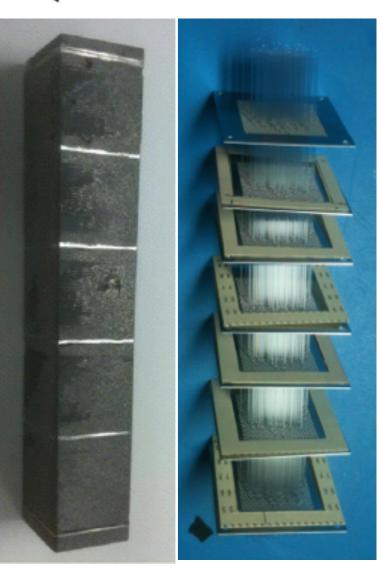
Light guides and SiPMs are attached to module ends to form towers



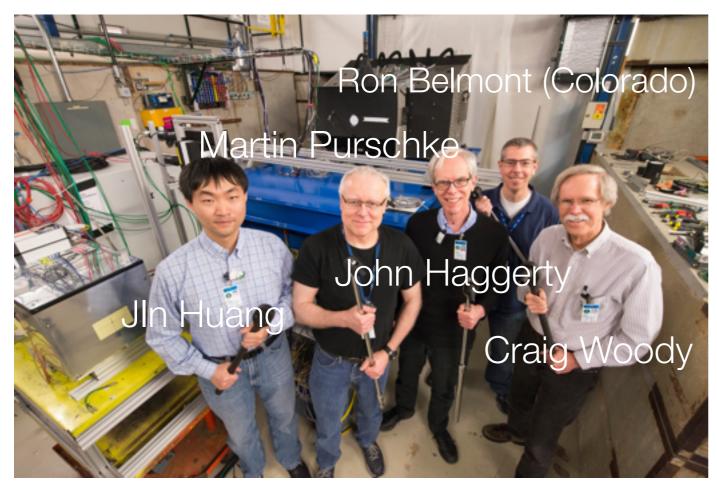


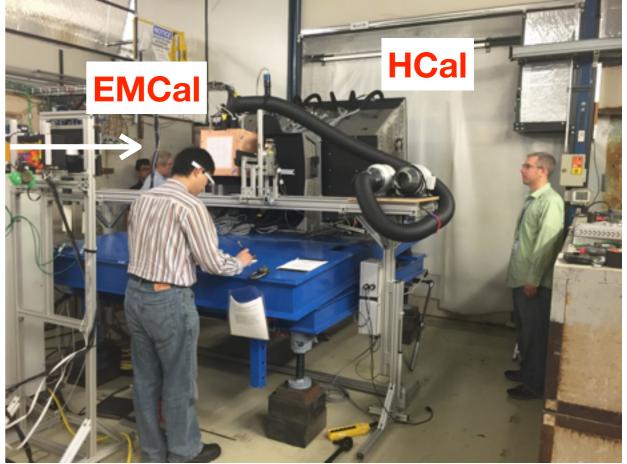
#### 2D Projective





# Proving R&D in test beam

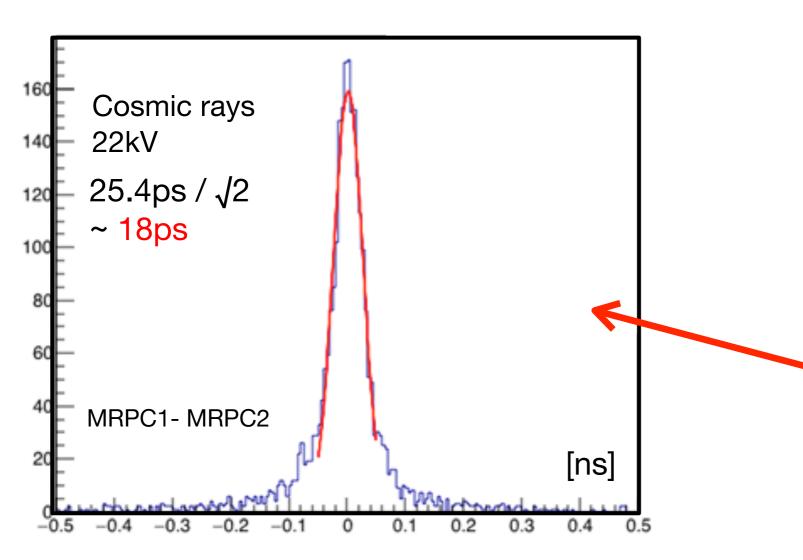




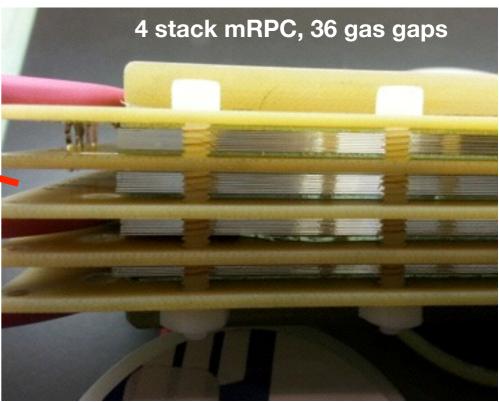
sPHENIX detector development coordinated with the collaboration most notably in beam tests at Fermilab and 2014 and 2016 involving over 30 collaborators from BNL and collaborating institutions

### High Performance TOF R&D

M. Chiu, A. Sukhanov (now at C-AD)







Investigating both mRPC and MCP-PMT technologies

Collaboration with UIUC, Howard, and ACU (M. Perdekamp and M. Chiu are co-PI's)

Funded by M. Chiu PECASE, EIC Generic R&D, and UIUC NSF Grant

Hosts of 4 ACU and 4 Howard undergraduate students in summer 2015 and 2016

Achieved ~20 ps with thin glass mRPC

Building sPHENIX compatible DRS4 readout board over next year

### PHENIX outreach

# Summer Sunday: Achim Franz (moved to Physics Dep't. ESSH)



#### Set up by BNL/PHENIX technicians





Summer Sunday 2016: 1400 visitors

### Engaging students in research

- PHENIX operations shifts, data monitoring, analysis
- Wide array of summer R&D work (EMCal, fast TOF, 3D printing of prototypes)
  - Abeliene Christian University (Rusty Towell and students)
  - Howard University (Marcus Alfred and students)
  - Stony Brook University (Spencer Locks (mech. engineering)

# Summary

- Group continues to be very successful with key responsibilities and activities:
   PHENIX operations and collaboration support, PHENIX and ATLAS HI analysis,
   R&D, planning for future scientific directions
- Scientific staff recently reduced by five FTEs, technical staff reduced by three FTEs;
   Goldhaber postdoc Perepelitsa now Asst. Prof. at Colorado
- Will rapidly ramp-down PHENIX operations effort (post R&R) towards 1.5 FTE
- Anticipating sPHENIX, a pivot in direction of group effort generic R&D, project management, support of test beam, hosting of sPHENIX collaboration. Aim to build and maintain "critical mass" of intellectual strength on key sPHENIX science – obvious target is jet physics
- Exciting, but very challenging period of transition. Maintaining group's scientific strength, to recruit and retain needed personnel, will require continued support from Laboratory to hire postdocs, junior staff, targeted hires.